ocean explorer www.oceanexplorer.noaa.gov

The NOAA Ship *Okeanos Explorer*

NOAA Ship *Okeanos Explorer:* America's Ship for Ocean Exploration Image credit: NOAA. For more information, see page 7 and the following Web site: *http://oceanexplorer.noaa.gov/okeanos/welcome.html*

Highlights in this Initial Inquiry Lesson

To Boldly Go…

An essential component of NOAA's Office of Ocean Exploration and Research mission is to enhance understanding of science, technology, engineering, and mathematics used in exploring the ocean, and build interest in careers that support ocean-related work. To help fulfill this mission, the Okeanos Explorer *Education Materials Collection is being developed to encourage educators and students to become personally involved with the voyages and discoveries of the* Okeanos Explorer*—America's first Federal ship dedicated to Ocean Exploration. Leader's Guides for Classroom Explorers focus on three themes: "Why Do We Explore?" (reasons for ocean exploration), "How Do We Explore?" (exploration methods), and "What Do We Expect to Find?" (recent discoveries that give us clues about what we may find in Earth's largely unknown ocean). Each Leader's Guide provides background information, links to resources, and an overview of recommended lesson plans on the Ocean Explorer Web site (*http://oceanexplorer.noaa.gov*). An Initial Inquiry Lesson for each of the three themes leads student inquiries that provide an overview of key topics. A series of lessons for each theme guides student investigations that explore these topics in greater depth. In the future additional guides will be added to the Education Materials Collection to support the involvement of citizen scientists.*

This is the initial inquiry lesson for the "Why Do We Explore?" theme in the Okeanos Explorer *Education Materials Collection, and guides students into an inquiry of reasons for ocean exploration. Other lessons for this theme guide additional inquiries into key topics of Ocean Exploration, Energy, Climate Change, Human Health, and Ocean Health.*

Focus

Ocean Exploration

Grade Level

Target Grade Level: 7-8; suggested adaptations for grades 5-6 and 9-12 can be found on pages 14-15.

Focus Question

Why do we explore the ocean?

Learning Objectives

Students will be able:

- To discuss why scientists believe there are important undiscovered features and processes in Earth's ocean.
- To discuss at least three motives that historically have driven human exploration.
- To explain why ocean exploration is relevant to climate change.
- To discuss at least three benefits that might result from ocean exploration.

Materials

- Internet and/or library access for student research
- Stiff paper such as card or cover stock
- Learning Shape patterns (photocopied from page 25, or downloaded from the Internet)
- Scissors or craft knives
- Markers and/or photo images
- Glue or glue stick
- Two stopwatches
- Seaweed crackers (from the Asian section of a grocery store) or other prizes

Audiovisual Materials

- Multimedia board, marker board, or overhead projector

Key Words and Concepts

Ocean exploration
NOAA Ship *Okeanos Explorer*
Climate change
Deep-sea medicines
pH
Ocean acidification
Telepresence
Methanogenic
Archaeobacteria

Background Information

> "We know more about the dead seas of Mars than our own ocean."
>
> – Jean-Michel Cousteau

In fact, our current estimation is that 95% of Earth's ocean is unexplored. At first, this may be hard to believe, particularly if

Seven Modern Reasons for Ocean Exploration

Ocean exploration supports and enhances the work of many individuals and organizations working on America's key science issues, including:

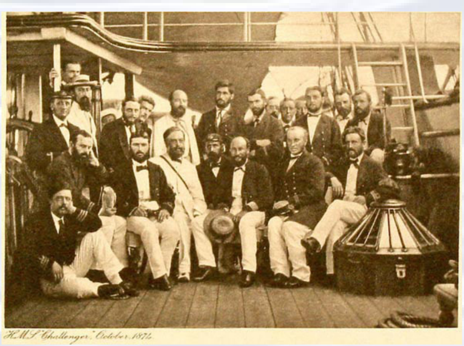
- ***Climate Change*** – The ocean has a major influence on weather and climate, but we know very little about deep-ocean processes that affect climate.
- ***Energy*** – Ocean exploration contributes to the discovery of new energy sources, as well as protecting unique and sensitive environments where these resources are found.
- ***Human Health*** – Expeditions to the unexplored ocean almost always discover species that are new to science, and many animals in deep-sea habitats have been found to be promising sources for powerful new antibiotic, anti-cancer and anti-inflammatory drugs.
- ***Ocean Health*** – Many ocean ecosystems are threatened by pollution, overexploitation, acidification and rising temperatures. Ocean exploration can improve understanding of these threats and ways to improve ocean health.
- ***Research*** – Expeditions to the unexplored ocean can help focus research into critical areas that are likely to produce tangible benefits.
- ***Innovation*** – Exploring Earth's ocean requires new technologies, sensors and tools and the need to work in extremely hostile environments is an ongoing stimulus for innovation.
- ***Ocean Literacy*** – Ocean exploration can help inspire new generations of youth to seek careers in science, and offers vivid examples of how concepts of biology, physical science, and earth science are useful in the real world.

For Recommended Lesson Plans on Ocean Exploration, Climate Change, Energy, Human Health, and Ocean Health, please see page 16.

we look at recent satellite maps of Earth's ocean floor. These maps seem to show seafloor features in considerable detail. But satellites can't see below the ocean's surface. The "images" of these features are estimates based on the height of the ocean's surface, which varies because the pull of gravity is affected by seafloor features. And if we consider the scale of these maps, it is easy to see how some things might be missed. To show our planet's entire ocean, a typical wall map has a scale of about 1 cm = 300 km. At that scale, the dot made by a 0.5 mm pencil represents an area of over 60 square miles! The reality is that most of the ocean floor has never been seen by human eyes.

Many Reasons to Explore

Historically, explorers have been driven by a variety of motives. For some, the primary reason to explore was to expand their knowledge of the world. For others, economic interests provided powerful incentives, and many expeditions have launched on such missions as finding a sea route to access the spices of Asia, or quests for gold, silver, and precious stones. Political power and the desire to control large empires motivated other explorations, as did the desire to spread religious doctrines. In the case of space exploration, additional reasons have been offered, including understanding our place in the cosmos, gaining knowledge about the origins of our solar system and about human origins, providing advancements in science and technology, providing opportunities for international collaboration, and keeping pace with other nations involved in developing space technology. The first ocean exploration for the specific purpose of scientific research is often considered to be the voyage of the HMS *Challenger*, conducted between 1872-1876 (visit http://oceanexplorer.noaa.gov/explorations/03mountains/background/challenger/challenger.html and http://www.coexploration.org/hmschallenger/html/AbouttheProject.htm for more information about the *Challenger* expedition and comparisons with modern oceanographic exploration).

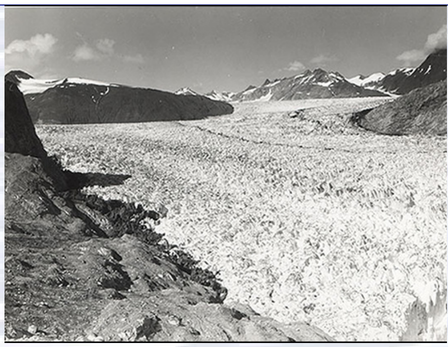


The science and ship crew of the HMS *Challenger* in 1874. The original crew of 216 had dwindled to 144 by the end of the long expedition. Image credit: NOAA.

Curiosity, desire for knowledge, and quest for adventure continue to motivate modern explorers. But today, there are additional reasons to explore Earth's ocean, including climate change, energy, human health, ocean health, innovation, research and ocean literacy.

Climate Change

Earth's average temperature is warmer than it has been at any time since at least 1400 AD. While debate continues about the causes of climate change and the relative importance of long-



The black and white photograph of Muir Glacier taken on August 13, 1941; the color photograph was taken from the same vantage on August 31, 2004. Between 1941 and 2004 the glacier retreated more than twelve kilometers (seven miles) and thinned by more than 800 meters (875 yards). Ocean water has filled the valley, replacing the ice of Muir Glacier; the end of the glacier has retreated out of the field of view. The glacier's absence reveals scars where glacier ice once scraped high up against the hillside. In 2004, trees and shrubs grew thickly in the foreground, where in 1941 there was only bare rock. Image credit: National Snow and Ice Data Center, W. O. Field, B. F. Molnia. *http://nsidc.org/data/glacier_photo/repeat_photography.html*

A marine worm, *Hesiocaeca methanicola*, on the surface of an orange gas hydrate. A variety of animals use methane hydrates as a source of energy. Image credit: Ian MacDonald. *http://oceanexplorer.noaa.gov/explorations/deepeast01/logs/sep23/media/icewormsmed_600.jpg*

term climate cycles, greenhouse gases, and other factors, it is clear that:

- Mountain glaciers are melting;
- Polar ice is decreasing;
- Springtime snow cover has reduced;
- Ground temperature has been increasing in many areas;
- Sea level has risen by several inches in the last 100 years.

Global climate is strongly influenced by interactions between Earth's atmosphere and ocean. One of the most significant climatic influences results from the "deep-ocean thermohaline circulation" (THC), which plays an important role in transporting heat, dissolved oxygen and nutrients. Dense water sinking in the North Atlantic Ocean is one of the principal forces that drives the circulation of the THC, and there are growing concerns about how these forces may be affected by changes in the Arctic climate. Warmer temperatures and increased freshwater inflow from melting ice cause seawater density to decrease. These changes could weaken the THC, including the Gulf Stream which is at least partially responsible for the fact that countries in northwestern Europe (Britain and Scandinavia) are about 9°C warmer than other locations at similar latitudes. In this way, warmer temperatures in the Arctic could result in colder temperatures in northwestern Europe.

For additional discussion about the THC, please see the *Why We Explore Leader's Guide for Classroom Explorers* pages 18-20.

Trends toward a warmer climate are having impacts in the tropics as well. Many scientists believe that the widespread decline of coral reefs is the result of accumulating stresses, one of which is increased water temperature. Other potential impacts of changing climate range from the possible extinction of species such as the polar bear to year-round access to sea routes through the Arctic. Ocean exploration can provide some of the essential knowledge about ocean-atmosphere interactions that is needed to understand, predict, and respond to these impacts.

For additional discussion about Climate Change, please see the *Why We Explore Leader's Guide for Classroom Explorers* page 4.

Energy

Methane hydrates are ice-like substances formed when molecules of water form an open lattice that surrounds molecules of methane without forming chemical bonds between the two materials. In deep-ocean sediments, conditions of low temperature and

Methane hydrate looks like ice, but as the "ice" melts it releases methane gas which can be a fuel source. Image credit: Gary Klinkhammer, OSU-COAS.

high pressure allow methane hydrate deposits to form. There is growing interest in these deposits as an alternative energy source, because the U. S. Geological Survey has estimated that on a global scale, methane hydrates may contain roughly twice the carbon contained in all reserves of coal, oil, and conventional natural gas combined. In addition, methane hydrates are associated with unusual and possibly unique biological communities containing previously-unknown species that may be sources of beneficial pharmaceutical materials.

Methane hydrates may also cause big problems, because when heated they can release large amounts of methane, a greenhouse gas that could have (and may already have had) major consequences to the Earth's climate. At the same time, a sudden release of pressurized methane gas may cause submarine landslides that in turn can trigger catastrophic tsunamis.

Besides methane hydrates, regions such as the Gulf of Mexico produce significant quantities of petroleum. Often, the presence of hydrocarbons at the surface of the seafloor is accompanied by "cold-seep communities" which are biological communities that derive their energy from gases (such as methane and hydrogen sulfide) and oil seeping out of sediments. In addition to locating new sources of hydrocarbon fuels, exploration of these communities frequently reveals species that are new to science and provides information on ecology and biodiversity that is needed to protect these unique and sensitive environments.

For additional discussion about Energy, please see the *Why We Explore Leader's Guide for Classroom Explorers* page 5.

Though they may be visually unimpressive, *Forcepia* sponges (left) are the source of the lasonolides and tunicates (right) are the source of ecteinascidin, potential new drugs for treating cancer. Image credit: NOAA.
http://oceanexplorer.noaa.gov/explorations/03bio/logs/hirez/lasonolide1_hirez.jpg
http://oceanexplorer.noaa.gov/explorations/03bio/logs/hirez/figure4_hirez.jpg

Human Health

Improving human health is another motive for ocean exploration. Almost all drugs derived from natural sources come from terrestrial plants. But recent explorations have found that some marine invertebrates such as sponges, tunicates, ascidians, bryozoans, and octocorals can also produce powerful drug-like substances. Many of these animals do not appear particularly impressive; yet, they produce more antibiotic, anti-cancer, and anti-inflammatory substances than any group of terrestrial organisms. The potential for discovering important new drugs from deep-ocean organisms is even greater when one considers that most of Earth's seafloor is still unexplored, and deep-sea explorations routinely find species that have never been seen before.

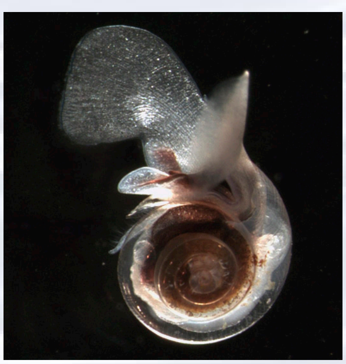
To date, most marine invertebrates that produce pharmacologically-active substances are sessile. Several reasons have been suggested to explain why these animals are particularly productive of potent chemicals. One possibility is that they use these chemicals to repel predators, since they are basically "sitting ducks." Since many of these species are filter feeders, and consequently are exposed to all sorts of parasites and pathogens in the water, they may use powerful chemicals to repel parasites or as antibiotics against disease-causing organisms. Competition for space may explain why some of these invertebrates produce anti-cancer agents. If two species are competing for the same piece of bottom space, it would be helpful to produce a substance that would attack rapidly dividing cells of the competing organism. Since cancer cells often divide more rapidly than normal cells, the same substance might have anti-cancer properties.

For additional discussion about Human Health, please see the *Why We Explore Leader's Guide for Classroom Explorers* page 7.

Many coral reefs are threatened by simultaneous impacts from pollution, rising temperatures, ocean acidification, and overfishing. Image credit: Thomas K. Gibson, Florida Keys National Marine Sanctuary. *http://www.photolib.noaa.gov/bigs/reef2583.jpg*

Ocean Health

The health of Earth's ocean is simultaneously threatened by over-exploitation of large species, destruction of benthic habitats, invasive species, rising temperatures, and pollution (Jackson, 2008). Recently, another stress has been recognized: ocean acidification. For many years, carbon dioxide in Earth's atmosphere has been increasing, and this has caused the ocean to become more acidic. Increased acidity interferes with the process of calcification through which many organisms produce shells and other skeletal structures. In addition to corals, shellfish, echinoderms, and many marine plankton also build body parts through calcification. Pteropods are planktonic snails that are an important component of food chains in high-latitude regions, and have been shown to have pitted or partially-dissolved shells in waters where carbonate ions are depleted.



Limacina helicina, a free-swimming planktonic snail. These snails, known as pteropods, form a calcium carbonate shell and are an important food source in many marine food webs. As levels of dissolved CO_2 in sea water rise, skeletal growth rates of pteropods and other calcium-secreting organisms will be reduced due to the effects of dissolved CO_2 on ocean acidity. Image credit: Russ Hopcroft, UAF/NOAA. *http://www.noaanews.noaa.gov/stories2006/images/pteropod-limacina-helicina.jpg*

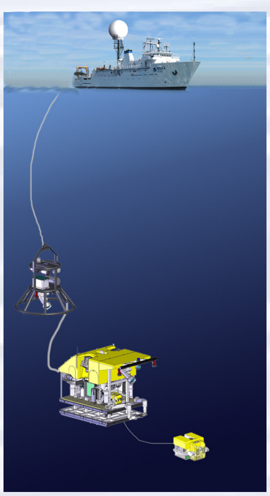
"Life will find a way," according to chaos theorist Ian Malcolm in *Jurassic Park* (Crichton, 1990). But the question is, "Which life?" Deep-sea explorers often find biological organisms thriving in conditions that would be extremely hostile to humans. But this does not mean that species can simply adapt to stresses from falling pH, rising sea levels, increasing temperatures, pollution and overfishing. We urgently need to learn more about ocean ecosystems and how they affect the rest of our planet. This is one of the most important modern reasons for ocean exploration. Without a doubt, human curiosity, the desire to understand our world, and the excitement of discovery are still among the reasons we explore Earth's ocean; but we also explore to survive.

***Okeanos Explorer* Vital Statistics:**

Commissioned: August 13, 2008; Seattle, Washington
Length: 224 feet
Breadth: 43 feet
Draft: 15 feet
Displacement: 2,298.3 metric tons
Berthing: 46, including crew and mission support
Operations: Ship crewed by NOAA Commissioned Officer Corps and civilians through NOAA's Office of Marine and Aviation Operations (OMAO); Mission equipment operated by NOAA's Ocean Exploration and Research Program

For more information, visit http://oceanexplorer.noaa.gov/okeanos/welcome.html.

Okeanos Explorer's Control Room is the exploration heart of the ship, serving a number of missions including processing of multibeam sonar for mapping, controlling video transmitted off the ship, and coordinating the interaction between those afloat and ashore. When ROVs are deployed, they are controlled here by a navigator, pilot and co-pilot. Images from various cameras on the ship, and on deployed ROVs, can be brought up on the large screens. Image credit: NOAA.
OE.ControlRoom.jpg



Okeanos Explorer's remotely-operated vehicle (ROV) system consists of a bell-shaped camera sled, a science-class ROV and a small xBot, all of which can operate as deep as 6000 meters. Image credit: NOAA.

For additional discussion about Ocean Health, please see the *Why We Explore Leader's Guide for Classroom Explorers* page 9.

NOAA Ship *Okeanos Explorer*

On August 13, 2008, the NOAA Ship *Okeanos Explorer* was commissioned as "America's Ship for Ocean Exploration"—the only U.S. ship whose sole assignment is to systematically explore our largely unknown ocean for the purposes of discovery and the advancement of knowledge. To fulfill its mission, the *Okeanos Explorer* has specialized capabilities for finding new and unusual features in unexplored parts of Earth's ocean, and for gathering key information that will support more detailed investigations by subsequent expeditions. These capabilities include:

- Reconnaissance within a search area to locate unusual features or anomalies;
- Underwater robots (remotely operated vehicles) that can investigate anomalies as deep as 6,000 meters;
- Underwater mapping using multibeam sonar capable of producing high-resolution maps of the seafloor to depths of 6,000 meters; and
- Advanced broadband satellite communication.

Broadband telecommunications capability provides the foundation for "telepresence," technologies that allow people to observe and interact with events at a remote location. This allows live images to be transmitted from the seafloor to scientists, educators and media ashore, and opens new educational opportunities which are a major part of the *Okeanos Explorer's* mission for advancement of knowledge. In addition, telepresence makes it possible for shipboard equipment to be controlled by scientists in shore-based Exploration Command Centers. In this way, scientific expertise can be brought to the exploration team as soon as discoveries are made, and at a fraction of the cost of traditional oceanographic expeditions.

Learning Procedure

This lesson is designed as a student inquiry into the question, Why do we explore the ocean? It is possible to make this inquiry an individual student assignment, but a group inquiry will probably produce a more dynamic exchange of ideas. The basic inquiry design is as follows: Assign the guidance questions below to groups of three or four students. Then have each group construct ocean exploration learning shapes as part of its inquiry, and use these shapes to reinforce concepts resulting from student inquiries. Finally, use oral reports from these groups as the basis for a full class discussion. The primary

Key Images and Video Resources

2003 Medicines from the Deep Sea Expedition *(Drugs from the sea)*: http://oceanexplorer.noaa.gov/explorations/03bio/logs/photolog/photolog.html

2003 Windows to the Deep Expedition *(Methane, cold seep communities)*: http://oceanexplorer.noaa.gov/explorations/03windows/logs/photolog/photolog.html

2005 GalAPAGoS: Where Ridge Meets Hotspot Expedition *(Hydrothermal vent communities)*: http://oceanexplorer.noaa.gov/explorations/05galapagos/logs/photolog/photolog.html

2006 Davidson Seamount: Exploring Ancient Coral Gardens Expedition *(Deep-water corals and oother species)*: http://oceanexplorer.noaa.gov/explorations/06davidson/logs/photolog/photolog.html

2006 Expedition to the Deep Slope *(Seep communities)*: http://oceanexplorer.noaa.gov/explorations/06mexico/logs/photolog/photolog.html

2006 Ring of Fire Expedition *(Underwater volcanoes, carbon dioxide venting)*: http://www.oceanexplorer.noaa.gov/explorations/06fire/logs/photolog/photolog.html

New Zealand American Submarine Ring of Fire 2007 Expedition *(Underwater volcanoes, exploration technology)*: http://oceanexplorer.noaa.gov/explorations/07fire/logs/photolog/photolog.html

Lophelia II 2008 Deepwater Coral Expedition – Reefs, Rigs and Wrecks *(Deep-water communities):* http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/photolog/photolog.html

curriculum topic of the lesson is Earth science. It is targeted to grade levels 7–8, but suggested adaptations for grades 5–6 and 9–12 are provided following the Learning Procedure section.

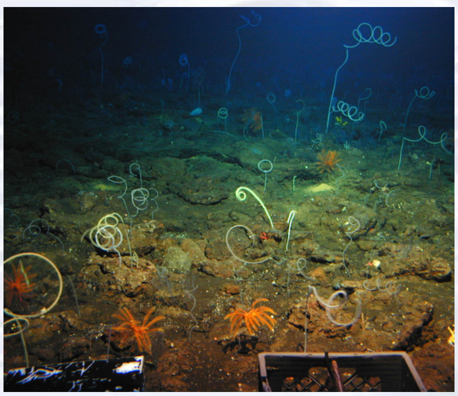
1. To prepare for this lesson,
   - Review introductory information on the NOAA Ship *Okeanos Explorer* at http://oceanexplorer.noaa.gov/okeanos/welcome.html
   - Review video presentations "Introduction to NOAA Ship *Okeanos Explorer*" (by John McDonough) and "Deep Ocean Exploration: New Discoveries and Implications for Our Warming Planet (by Steve R. Hammond) – From the *Okeanos Explorer* education page (http://oceanexplorer.noaa.gov/okeanos/edu/welcome.html) click on "Resources and Links," then scroll down to the link for these presentations.
   - (optional) Download some images from sources provided in the sidebar (see left) for use during discussions.
   - (optional) Additional information about the history of ocean exploration is available at http://oceanexplorer.noaa.gov/history/history.html.

2. Briefly introduce the NOAA Ship *Okeanos Explorer*, emphasizing that this is the first Federal vessel specifically dedicated to exploring Earth's largely unknown ocean. Be sure students understand the concept of "telepresence," and that telepresence technology will make it possible for people (including students in classrooms) to participate in these explorations from locations thousands of miles away.

3. Tell students that their assignment is to answer the question, "Why do we explore the ocean?" Each student or student group should prepare an oral report that addresses the following inquiry Guidance Questions:
   (1) "We know more about the dead seas of Mars than our own ocean." (Jean-Michel Cousteau). How can this be true? And even if it is, so what? Isn't the deep-ocean more or less the same, wherever you go?
   (2) Historically, what are some reasons for human exploration?
   (3) Today, are there any other reasons to explore Earth's ocean?
   (4) If time permits, you may also want to have students address the question, "Who are today's ocean explorers?" and refer them to the Ocean Explorer OceanAGE Careers Web page (http://oceanexplorer.noaa.gov/edu/oceanage/welcome.html**).**

   - The following links to Web pages for Ocean Explorer expeditions provide examples of some benefits that can

Carbon dioxide bubbles from a volcanic pit on the Submarine Ring of Fire can affect water acidity in nearby communities. The overall effect of volcanic gases on the acidity of the ocean is not known. Image credit: NOAA. *http://www.noaanews.noaa.gov/stories2006/images/undersea-volcano-sulfur-cloud-bubbles.jpg*



Life abounds around a vent field around Volcano 19 in the southwest Pacific Ocean. Until recently, these deep-sea communities were entirely unknown. Image credit: NOAA/NURP. *http://www.noaanews.noaa.gov/stories2005/images/ventfield-lifew2005.jpg*

Ocean explorers study sea ice ecosystems in the Arctic Ocean which is experiencing rapid climate change. Image credit: Emory Kristof. *http://oceanexplorer.noaa.gov/explorations/02arctic/logs/hirez/22_diver_hirez.jpg*

result from ocean exploration:

Energy:
- http://oceanexplorer.noaa.gov/explorations/03windows/welcome.html
- http://oceanexplorer.noaa.gov/explorations/07mexico/welcome.html

Human Health:
- http://oceanexplorer.noaa.gov/explorations/03bio/welcome.html

Ocean Health:
- http://oceanexplorer.noaa.gov/explorations/08bonaire/welcome.html

Climate Change:
- http://oceanexplorer.noaa.gov/explorations/06arctic/welcome.html
- http://oceanexplorer.noaa.gov/explorations/02arctic/welcome.html

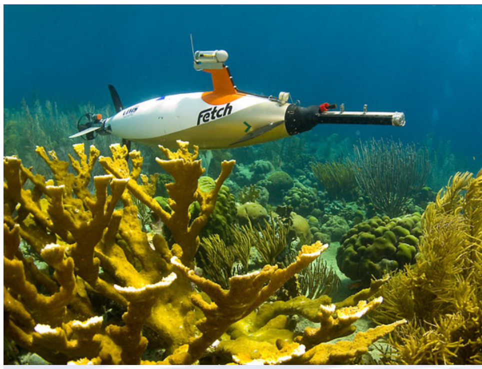
4. Have each group make an oral presentation of their findings. When all groups have reported, facilitate a class discussion of these results. Key points for Guidance Questions should include:

(1) "We know more about the dead seas of Mars than our own ocean." (Jean-Michel Cousteau). How can this be true? And even if it is, so what? Isn't the deep-ocean more or less the same, wherever you go?

Key Points: Considering the difficulty of photographing large areas of the ocean floor, as well as the three-dimensional nature of ocean habitats, it is easy to see how we might know more about the surface of Mars. While many people think that the deep-ocean is more or less homogenous over large areas, recent discoveries of hydrothermal vents, deep-sea cold seeps, underwater volcanoes, seamounts, and other features suggest that there is much more variety than was once supposed. Images from "Key Image and Video Resources" (see sidebar on page 8) may enhance discussions.

(2) Historically, what are some reasons for human exploration?

Key Points: Students may suggest a considerable variety of motives, including to gain knowledge about the world, obtain economic benefits, increase political power, spread religious doctrines, advance science and technology, and keeping pace with other nations. Simple curiosity and/or the "challenge of the unknown" are also valid suggestions, though often these are accompanied by more pragmatic considerations as well.



Coral reefs around the world are showing signs of severe stress; yet, the reefs on the coast of Bonaire are amazingly healthy. The Bonaire 2008 expedition used autonomous underwater vehicles to help find some of the reasons. Image credit: Bonaire 2008 Expedition. *http://oceanexplorer.noaa.gov/explorations/08bonaire/logs/summary/media/elkhorn_coral.html*

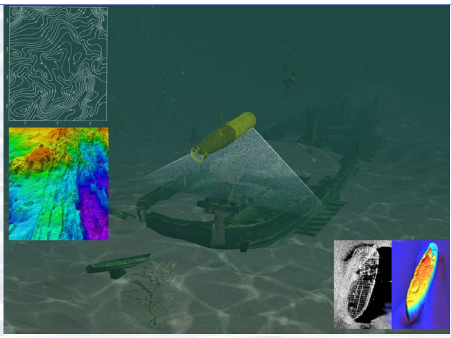
As the oil and gas industry continues to search for energy reserves in deep waters of the the Gulf of Mexico, it is critical to know more about deepwater organisms so that sensitive biological habitats may be protected. The *Lophelia* II 2008 – Deepwater Coral Expedition: Reefs, Rigs, and Wrecks explored new deepwater coral communities at natural and man-made sites in the deep Gulf of Mexico. In Green Canyon, deepwater corals *Lophelia pertusa* create habitat for a number of other species. Image credit: Chuck Fisher. *http://oceanexplorer.noaa.gov/explorations/08lophelia/logs/sept24/media/green_canyon_lophelia_600.jpg*

Harbor Branch Oceanographic Institution researcher Dr. Shirley Pomponi removes a bright yellow sponge from a rock collected by an underwater robot during the 2003 Medicines from the Deep Sea expedition. Extracts from the sponge were tested for anti-cancer properties. Image credit: Laura Rear, NOAA. *http://oceanexplorer.noaa.gov/explorations/03bio/logs/summary/media/10249_bio_600.jpg*

(3) Today, are there any other reasons to explore Earth's ocean?

Key Points: Ocean Exploration contributes directly to issues and needs that are widely acknowledged to be national priorities, including:

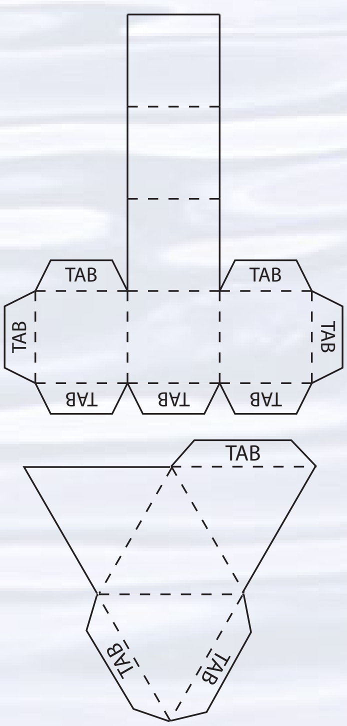
- *Climate Change* – The ocean has major influence on Earth's climate; but we don't even know, let alone understand, all of the processes involved in the interactions between the ocean and climate, because most of the ocean is unknown. You may want to show images that document the decline in polar sea ice and/or glaciers (http://www.nasa.gov/centers/goddard/images/content/94364main_STILLsea_ice_yearly.1979.tif; http://www.nasa.gov/images/content/190554main_AMSR_E_09_14_2007_r1.1536.tif; and http://nsidc.org/data/glacier_photo/repeat_photography.html).
- *Energy* – Methane hydrates are an example of potential alternative sources of energy. The U.S. Geological Survey estimates that methane hydrates may contain roughly twice the carbon contained in all reserves of coal, oil, and conventional natural gas combined. Students should also realize that in addition to discovering new energy sources, ocean exploration is also concerned with protecting unique and sensitive environments where these resources are found.
- *Human Health* – Animals in deep-sea habitats have been found to be promising sources for powerful new antibiotic, anti-cancer and anti-inflammatory drugs. Expeditions to the unexplored ocean almost always discover species that are new to science, creating a high probability of finding important new natural products.
- *Ocean Health* – Rapid changes in Earth's climate, pollution, and overfishing are having serious negative impacts on some ocean ecosystems. Mention the potential impact of rising temperatures on tropical species that are already near their upper thermal tolerance limit, such as corals. Be sure students understand that corals are also subject to a variety of other stresses, and the combined stress from multiple sources amplifies the impacts of climate change. If it is not mentioned by students, introduce the effect of increased atmospheric carbon dioxide on ocean pH. Appendix I (page 24) describes a simple demonstration of the impact of dissolved carbon dioxide on pH. Be sure students understand that while there is some disagreement about the connection between climatic temperature increase



Ocean exploration requires ongoing technological innovation. Situational Awareness is one such innovation used in Autonomous Underwater Vehicles (AUVs) to provide the ability to sense their surroundings and avoid obstacles. Image credit: NOAA. *http://oceanexplorer.noaa.gov/explorations/08auvfest/background/hires/auv_concept_hires.jpg*

Okeanos Explorer's prominent VSAT (Very small aperture terminal) dome enables satellite communications between explorers ashore and afloat and provides multiple high-definition video streams for widespread dissemination. Image credit: NOAA.

Figure 1: Simple Learning Shapes



and carbon dioxide from human activity, the increase in atmospheric CO_2 and decline in ocean pH are not theoretical; these changes have been confirmed by actual measurements.

- *Research* – Expeditions to the unexplored ocean can help focus research into critical geographic and subject areas that are likely to produce tangible benefits. Telepresence technology aboard the *Okeanos Explorer* allows many researchers to participate at a fraction of the cost of traditional expeditions, as well as opportunities for students and the general public to have a first-hand look at the processes of scientific research.
- *Technological Innovation* – The challenges of working in the extremely hostile environments of the deep-ocean are an ongoing stimulus for technology innovation and development.
- *Science Education* – Ocean exploration can help inspire new generations of youth to seek careers in science, and offers vivid examples of how concepts of biology, physical science, and Earth science are useful in the real world. Similarly, the challenges of exploring the deep-ocean can provide the basis for problem-solving instruction in technology and engineering. Ocean exploration also provides an engaging context for improving ocean literacy; understanding how the ocean influences our lives, and how we influence the ocean. Widespread ocean literacy is increasingly vital as we confront issues such as ocean health and climate change.

5. **Ocean Exploration Learning Shapes and the Ocean Exploration Bowl Game** – Inspired by the *Okeanos Explorer's* satellite dome, these are geometric solids constructed by students to provide three-dimensional surfaces for displaying concepts, images, and other information. Many curricula require students to communicate ideas to other groups, and Learning Shapes provide a novel and versatile tool that can enhance communication activities. Learning Shapes can be constructed in many sizes, shapes, and colors using a variety of materials (stiff paper such as card stock is inexpensive, versatile, and widely available). In addition to their use as a learning and communication tool, constructing Learning Shapes also provides a basis for potential cross-curricular activities with Language Arts and Mathematics, and helps develop engineering skills including layout and design, material selection, modeling, and prototyping. The simplest

NOAA's Ocean Explorer Gallery offers images of unusual organisms from the deep-ocean that are ideal for Ocean Exploration Learning Shapes, such as this spiny crab, deep-water anemone, and Shaefer's anglerfish.
Image credit: NOAA.
http://oceanexplorer.noaa.gov/explorations/04fire/logs/hirez/spinycrab_hirez.jpg
http://oceanexplorer.noaa.gov/explorations/02quest/logs/jun16/media/02_ANEMO.JPG
http://oceanexplorer.noaa.gov/explorations/04etta/logs/hirez/bubba_mouth_hirez.jpg

Learning Shapes are tetrahedrons and cubes, which provide four and six surfaces respectively and can be constructed as illustrated in Figure 1. There are numerous books and Web sites that describe how to construct various polygons.

To reinforce concepts resulting from student inquiries, students construct Learning Shapes to summarize modern reasons for ocean exploration (i.e., climate change, energy, human health, ocean health, research, technological innovation and science education), and will use their creations to play a competitive "Ocean Exploration Bowl" game.

a. Each student group should construct four octahedrons using the pattern illustrated in Figure 2. If larger Learning Shapes are desired, the pattern can be copied onto tabloid-size paper or cover stock with an enlarging photocopier.

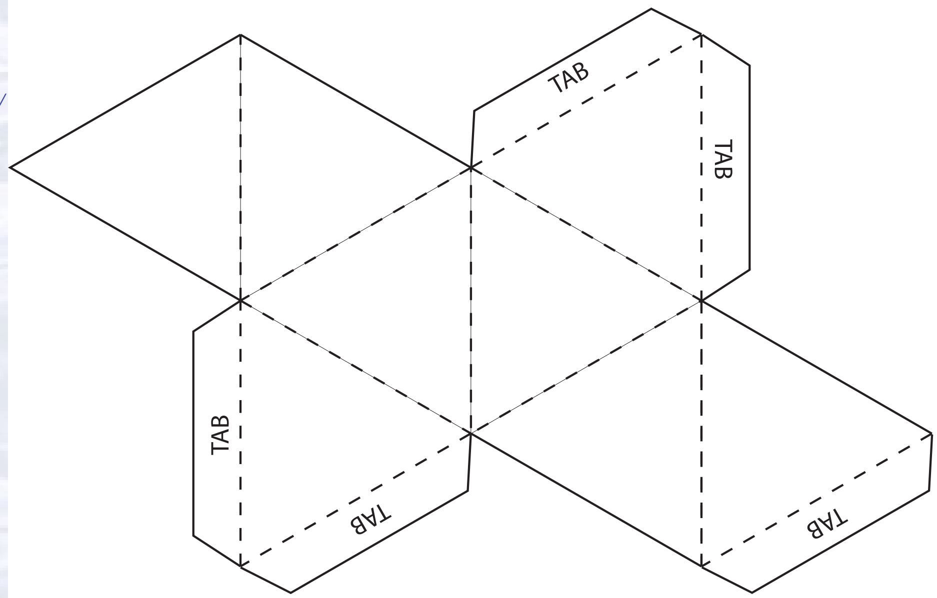


Figure 2:
Ocean Exploration Learning Shape: Octahedron
Using photocopies of the larger pattern found on page 25, fold on dotted lines, and glue tabs under matching edges.

b. Students should attach images or text to the eight faces of the Learning Shapes as follows:
- One Learning Shape should have images attached to seven faces that illustrate the seven modern reasons for ocean exploration discussed above. So one face will have an image representing climate change, another face will have an image that represents energy, and so on. The remaining face should have an image of the *Okeanos Explorer*. Since this eighth face is used as a "neutral" image, it could be completely blank, but using an image of America's Ship for Ocean Exploration makes the Learning Shape much more interesting!
- One of the Learning Shapes should have text on seven faces that provide a descriptive title for one of the

Learning Shapes are fun to make! Image credit: Mel Goodwin.

modern reasons for ocean exploration. So there should be one face that says "Energy," another that says "Ocean Health," and so on. The eighth face should have an image of the *Okeanos Explorer*, or other "neutral" image.

- The two remaining Learning Shapes should also have one "neutral" face containing an image of the *Okeanos Explorer*. The other seven faces should contain brief text describing a single fact about one of the seven modern reasons for ocean exploration, with a different reason represented on each of the seven faces. So one of the shapes might have a face that says "Methane hydrates are a potential energy source found in the deep ocean" (representing energy as a reason for exploration), another face that says "Deep-sea animals can be promising sources of new drugs" (representing human health as a reason for exploration), and so on.

Note: It is easier to attach images and text before Learning Shapes are fully assembled. Cut out and pre-fold the Shapes, but attach images and/or text before gluing the tabs into place.

When all four Learning Shapes are completed, it should be possible to orient the shapes so that the upper face of one shape shows a picture representing one of the modern reasons for ocean exploration, the upper face of another shape shows a descriptive title stating the reason in words, and the upper faces of the remaining two shapes shows facts relevant to that reason. It should also be possible to orient the four shapes so that the upper face shows a "neutral" image that is not specifically related to a specific reason to explore the ocean.

c. Now it's time to play "Ocean Exploration Bowl!" The object of this game is for student groups to correctly associate, in the shortest possible time, descriptive titles and relevant facts with an image representing a reason for exploration. Groups compete one at a time, and when all groups have competed, one round has been completed. When a group has finished, ask members of other groups to verify that the selected title and facts correctly match the image. Students have to pay attention to make this verification, and because play proceeds rapidly from group to group there is minimal "down time" during which students may become distracted.

Assign two students to act as timekeepers. Since groups compete one at a time, timekeepers can be members of other competing groups. Provide each timekeeper with a stopwatch. Have one group arrange their four Learning Shapes on a desk or table so that the image of *Okeanos Explorer* (or other "neutral" image) shows on the upper face of each Learning Shape.

You (the educator) should pick up the Learning Shape that has images attached, hold it out of students' sight, and orient the Learning Shape so that one of the images representing a reason for ocean exploration is facing the palm of your hand. Put the Learning Shape back onto the table, and say "Boldly Go!" as you remove your hand. The timekeepers should start their stopwatches as soon as you say "Boldly Go!", and students in the group should orient the remaining three cubes as quickly as possible so that the appropriate descriptive title and two relevant facts are facing upward. As soon as they have done this, the group should say "Discovery!" which is the signal for the timekeepers to stop their stopwatches. Have group members state their reason for ocean exploration, and the relevant facts. Record the average from the two stopwatches on a score sheet for the competing group.

Repeat this process for the remaining groups. At least three rounds should be completed to cover all seven reasons and a good selection of relevant facts. When the winning group has been determined (by the shortest average time over all rounds), award prizes such as small bags of seaweed crackers, or other ocean-related items. Be sure every group receives something, but it's fine if the winner's share is larger!

If time is short, you may want to have groups construct only the first Learning Shape with images, then have group members state as many relevant facts as possible when a particular image is turned face up. This eliminates the need for timekeepers, but you should probably have several rounds since student inquiries are likely to yield more facts for some reasons than others.

Adaptations for Other Grade Levels

Considerations for Grades 5-6 – Some students may not be familiar with hydrothermal vents, deep-sea cold seeps, underwater volcanoes, and seamounts that have been relatively recently discovered, so be sure to have images of these habitats available to show after receiving students' comments on the Cousteau quotation. Similarly, students may not be aware of the potential for new medicines or alternative energy sources from deep-sea ecosystems. Depending upon their existing knowledge, you may want to focus primarily upon these potentials as contemporary reasons for ocean exploration, since the relationship between deep-ocean processes and climate change may be difficult to understand at this grade level. In addition, students may be intrigued by how little is known about the deep-ocean, and may feel that this is sufficient justification for exploration. Be sure students understand that the *Okeanos Explorer* is the first U.S. ship to be dedicated specifically to exploring the largely unknown ocean.

Considerations for Grades 9-12 – Ocean acidification, pH, buffers, carbon dioxide sources and sinks, methane hydrates, deep-sea medicines, and deep-ocean habitats (hydrothermal vents, deep-sea cold seeps, underwater volcanoes, and seamounts) can all be explored in greater detail. Consider assigning these topics to individual student groups prior to beginning a discussion focused on ocean exploration. When groups have completed their reports, lead a discussion to address the Guidance Questions and invite appropriate groups to present relevant information from their reports in the context of "why explore."

The BRIDGE Connection

www.vims.edu/bridge/ – In the navigation menu on the left side of the Web page, click "Ocean Science Topics," then "Human Activities," then "Technology" for links to information and activities involved with ocean exploration, including satellites, underwater robots, and deep-sea medicines.

The "Me" Connection

Have students write a brief essay about what ocean life might be like in the second half of the 21st century, and how ocean exploration might affect that future.

Connections to Other Subjects

English/Language Arts, Mathematics, Social Studies

Assessment

Written reports may be required as part of Learning Procedure Step 3. These reports, discussions and/or the Ocean Exploration Bowl game provide a basis for assessment.

Multimedia Discovery Missions

http://www.oceanexplorer.noaa.gov/edu/learning/welcome.html
Click on the links to Lessons 3, 5, 12, 13, and 15 for interactive multimedia presentations and Learning Activities on Deep-Sea Corals, Chemosynthesis and Hydrothermal Vent Life, Food, Water, and Medicine from the Sea, Ocean Pollution, and Seamounts.

Recommended Lesson Plans for Further Exploration of Key Topics

To access these lessons, go to http://oceanexplorer.noaa.gov/okeanos/edu/welcome.html. *While each lesson is targeted toward a specific grade level, most can be adapted for use in other grades as well.*

- **Ocean Exploration**

Grades 5-6

Journey to the Unknown
Students will experience the excitement of discovery and problem-solving to learn what organisms could live in extreme environments in the deep ocean, and will understand the importance of ocean exploration.
Hands-on activity: Posterize images and construct an ultraviolet LED poster illuminator

Grades 7-8

Come on Down!
Students will research the development and use of research vessels/vehicles used for deep-ocean exploration; calculate the density of objects by determining the mass and volume; and construct a device that exhibits neutral buoyancy.
Hands-on activity: Construct an electronic force sensor

Grades 9-12

Calling All Explorers
Students will learn what it means to be an explorer, both modern and historic; recognize that not all exploration occurs on land; understand the importance of curiosity, exploration, and the ability to document what one studies; gain insight into the vastness of unexplored places in the deep sea; and gain appreciation of science mentors and role models.
Hands-on activity: "Your Own Expedition of Discovery" (geocaching)

• Climate Change

Grades 5-6

The Methane Circus

Students will describe the overall events that occurred during the "Cambrian explosion," explain how methane hydrates may contribute to global warming, and describe the reasoning behind hypotheses that link methane hydrates with the Cambrian explosion.

Hands-on activity: Create model fossils of organisms that appeared during the Cambrian explosion

Grades 7-8

Where Have All the Glaciers Gone?

Students will describe how climate change is affecting sea ice, vegetation, and glaciers in the Arctic region, explain how changes in the Arctic climate can produce global impacts, and will be able to provide three examples of such impacts. Students will also explain how a given impact resulting from climate change may be considered 'positive' as well as 'negative', and will be able to provide at least one example of each.

Hands-on activity: Make a photocube showing changes in glaciers

Grades 9-12

History's Thermometers

Students will explain the concept of paleoclimatological proxies, learn how oxygen isotope ratios are related to water temperature, and interpret data on oxygen isotope ratios to make inferences about climate and climate change in the geologic past.

Hands-on activity: Create a scientific poster

• Energy

Grades 5-6

Animals of the Fire Ice

Students will define and describe methane hydrate ice worms and hydrate shrimp, infer how methane hydrate ice worms and hydrate shrimp obtain their food, and infer how methane hydrate ice worms and hydrate shrimp may interact with other species in the biological communities of which they are part.

Hands-on activity: Model a methane hydrate molecule

Grades 7-8

Oceans of Energy

Students will describe forms of energy, explain how each form is used by humans, and discuss at least three ways that energy can be obtained from the ocean.

Hands-on activity: Build a simple turbine

Grades 9-12

What's the Big Deal?

Students will define methane hydrates and describe where these substances are typically found and how they are believed to be formed. Students will also describe at least three ways in which methane hydrates could have a direct impact on their own lives, and describe how additional knowledge of methane hydrates could provide human benefits.

Hands-on activity: Construct a methane hydrate molecule

- **Human Health**

Grades 5-6

Microfriends

Students will describe at least three ways in which microorganisms benefit people, describe aseptic procedures, and obtain and culture a bacterial sample on a nutrient medium.

Hands-on activity: Bacteria culture

Grades 7-8

What Killed the Seeds?

Students will explain and carry out a simple process for studying the biological effects of chemicals and will be able to infer why organisms such as sessile marine invertebrates appear to be promising sources of new drugs.

Hands-on activity: Bioassay

Grades 9-12

Watch the Screen

Students will be able to explain and carry out a simple process for screening natural products for biological activity, and will be able to infer why organisms such as sessile marine invertebrates appear to be promising sources of new drugs.

Hands-on activity: Screening plant products for antibacterial properties

• Ocean Health

Grades 5-6

Build Your Own Ecosystem

Students will identify key functions that are present in healthy ocean ecosystems, and discuss how these functions are met by living and non-living components in a model aquatic ecosystem.

Hands-on activity: Build an ecosystem in a bottle

Grades 7-8

Stressed Out!

Students will identify stresses that threaten the health of ocean ecosystems, explain natural and human-caused processes that contribute to these stresses, and discuss actions that may be taken to reduce them.

Hands-on activity: Experiments with a tabletop biosphere

Grades 9-12

Off Base

Students will define pH and buffer, explain in general terms the carbonate buffer system of seawater, explain Le Chatelier's Principle, predict how the carbonate buffer system of seawater will respond to a change in concentration of hydrogen ions, identify how an increase in atmospheric carbon dioxide might affect the pH of the ocean, and discuss how this alteration in pH might affect biological organisms.

Hands-on activity: Experiment with pH buffers

Other Resources

The Web links below are provided for informational purposes only. Links outside of Ocean Explorer have been checked at the time of this page's publication, but the linking sites may become outdated or non-operational over time.

http://celebrating200years.noaa.gov/edufun/book/welcome.html#book – A free printable book for home and school use introduced in 2004 to celebrate the 200th anniversary of NOAA; nearly 200 pages of lessons focussing on the exploration, understanding, and protection of Earth as a whole system.

Allsopp, M., R. Page , P. Johnston , and D. Samtillo. 2007. Oceans in Peril. Worldwatch Report 174. Worldwatch Institute, Washington, DC. 56 pp.

Jackson, J. B. C. 2008. Ecological extinction and evolution in the brave new ocean. Proceedings of the National Academy of Sciences, August 12, 2008 Vol. 105 No. Supplement 1 11458-11465. Abstract available online at http://www.pnas.org/content/105/suppl.1/11458

http://www.ucar.edu/communications/Final_acidification.pdf – "Impacts of Ocean Acidification on Coral Reefs and Other Marine Calcifiers: A Guide for Future Research;" Report from a Workshop Sponsored by the National Science Foundation, the National Oceanic and Atmospheric Administration, and the U.S. Geological Survey

Havenhand, J.N., F.-R. Buttler, M.C. Thorndyke, J.E. Williamson. 2008. Near-future levels of ocean acidification reduce fertilization success in a sea urchin. Current Biology, 18:R651-R652

http://www.terrain.org/articles/21/burns.htm – Article on ocean acidification

http://www.oceana.org/climate/impacts/acid-oceans/ – *Oceana* article on ocean acidification

http://www.usgcrp.gov/usgcrp/documents/mmbralmanac.html – "Is the Climate Changing? Indeed It Is," by Michael MacCracken, Director of the Office of the U.S. Global Change Research Program, and Tom Karl, Senior Scientist, National Climatic Data Center, NOAA

http://nsidc.org/data/glacier_photo/repeat_photography.html – Repeat Photography of Glaciers; photographs taken from the same vantage point, but years apart in time, that provide striking visual evidence of climate change; from the National Snow and Ice Data Center

http://oceanexplorer.noaa.gov/history/history.html – Comprehensive look at NOAA's 200-year history of ocean exploration

http://oceanexplorer.noaa.gov/history/quotes/explore/explore.html – Quotations about "Why Explore?"

http://www.arctic.noaa.gov/essay_bond.html – "Why is the Arctic important?" by Nick Bond, Jim Overland and Nancy Soreide, NOAA Pacific Marine Environmental Laboratory

Crichton, M. 1990. *Jurassic Park*. Ballantine Books, New York

http://www.pmel.noaa.gov/co2/OA/index.html – Ocean acidification Web page from NOAA's Pacific Marine Environmental Laboratory

National Science Education Standards

Content Standard A: Science As Inquiry

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science

- Properties and changes of properties in matter

Content Standard C: Life Science

- Structure and function in living systems
- Populations and ecosystems
- Diversity and adaptations of organisms

Content Standard D: Earth and Space Science

- Structure of the Earth system

Content Standard E: Science and Technology

- Abilities of technological design
- Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

- Personal health
- Populations, resources, and environments
- Natural hazards
- Risks and benefits
- Science and technology in society

Content Standard G: History and Nature of Science

- Science as a human endeavor
- History of science

Ocean Literacy Essential Principles and Fundamental Concepts

Essential Principle 1.

The Earth has one big ocean with many features.

Fundamental Concept a. The ocean is the dominant physical feature on our planet Earth—covering approximately 70% of the planet's surface. There is one ocean with many ocean basins, such as the North Pacific, South Pacific, North Atlantic, South Atlantic, Indian and Arctic.

Fundamental Concept h. Although the ocean is large, it is finite and resources are limited.

Essential Principle 3.
The ocean is a major influence on weather and climate.

Fundamental Concept a. The ocean controls weather and climate by dominating the Earth's energy, water and carbon systems.

Fundamental Concept e. The ocean dominates the Earth's carbon cycle. Half the primary productivity on Earth takes place in the sunlit layers of the ocean and the ocean absorbs roughly half of all carbon dioxide added to the atmosphere.

Fundamental Concept f. The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon and water.

Essential Principle 6.
The ocean and humans are inextricably interconnected.

Fundamental Concept a. The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and nearly all Earth's oxygen. It moderates the Earth's climate, influences our weather, and affects human health.

Fundamental Concept b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.

Fundamental Concept e. Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.

Fundamental Concept g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

Essential Principle 7.
The ocean is largely unexplored.

Fundamental Concept a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.

Fundamental Concept b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.

Fundamental Concept c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.

Fundamental Concept d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.

Fundamental Concept f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Send Us Your Feedback

We value your feedback on this lesson, including how you use it in your formal/informal education setting.
Please send your comments to:
oceanexeducation@noaa.gov

For More Information

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http://oceanexplorer.noaa.gov

Appendix I

How to Demonstrate the Effect of Dissolved Carbon Dioxide on pH

Materials

Optional for demonstrating effect of dissolved carbon dioxide on pH:

- Drinking straw
- 100 ml of distilled water
- 100 ml of seawater (natural or artificial)
- Glass jar or beaker, about 200 ml capacity
- pH testing strips or indicator solution (from aquarium supply store)

Audio/Visual Materials

(Optional) Overhead projector, Smart Board®, or digital projector for displaying downloaded images

Teaching Time

One or two 45-minute class periods

Seating Arrangement

Classroom style or groups of three or four students

Maximum Number of Students

32

Learning Procedure

1. Pour approximately 100 ml of distilled water into a clean container. Test the pH of the water with pH testing paper or a pH meter, and record the measurement.
2. Blow through a drinking straw into the water for 60 seconds (take a breath when necessary!).
3. Test the pH again, and compare this measurement with the pH of the water in Step 1.
4. Repeat Steps 1 through 3 using seawater (artificial or natural) instead of distilled water. A buffer is a solution that tends to resist changes in pH. Do your results suggest that seawater may act as a buffer?

Figure 2:
Ocean Exploration Learning Shape Octahedron